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Design and Construction of 5 Kw Capacity Pelton Turbine in Pertegi Village, Pungga Hall, Parmonangan District, North Tapanuli

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A B S T R A C T

Micro Hydro Power Plants (PLTMH) are a new energy source that is cheaper and available in large quantities. Therefore, a Micro Hydro Power Plant (PLTMH) was designed as a source of electrical energy in the village of Mid-Punggah Hamlet, Parmonangan District, North Tapanuli Regency, using a Pelton type turbine. Pelton turbines are considered to have relatively stable performance, meaning that changes in efficiency with varying loads are not too large. Pelton turbine design utilizes Q (Discharge), H (Head) as initial data which refers to the characteristics of the Pelton Turbine. The number of nozzles to emit water that will fall onto the turbine wheel is 2 and has a diameter (d) of 20 mm. The number of turbine blades (Z) is 33, the turbine width (b) is 64 mm and the blade length (h) is 70 mm. This Pelton turbine was designed using Autocad 2007 software. The materials used were 201 stainless steel plate with a thickness of 5 mm, black steel plate with a thickness of 12 mm and 2-4 inch pipes with a thickness of 2.5 mm. The designed dimensions are 1500 mm x 500 mm x 700 mm.

Keywords:
Micro Hydro Power Plant
Pelton Turbine
Energy Efficiency
Turbine
Design

I. Introduction

Electrical energy is a source of energy that arises due to the movement of electrons from one location to another. This movement of electrons occurs due to the potential difference between two points. Electrical energy is generated when electrons flow through a conductor, such as copper wire. When there is an electric voltage at the end of the conductor, electrons begin to move from one end to the other. In general, electrical energy can be generated from various sources, such as hydroelectric power plants, solar power, and fossil fuels. This energy source does not produce greenhouse gas emissions, so it is categorized as clean energy. Well, here are some sources of electrical energy.

Turbines can be divided into two main types: reaction turbines and impulse turbines. Reaction turbines utilize all available water energy to generate power. Meanwhile, impulse turbines operate by rotating the runner through a high-speed water jet, where the pressure is obtained from the height of the water as it exits through the nozzle.

The Pelton turbine is a type of impulse turbine, namely a turbine that is driven by the kinetic energy of water. The high-speed water jet from the nozzle hits the bucket runner, moving it. After that, the water comes out at a low speed, indicating that some of its energy is not fully absorbed by the runner. [1].

The village of Tengah, Dusun Punggah, Parmonangan District, North Tapanuli Regency is located on a mountain far from the reach of Parmonangan District, this is what causes them not to have received electricity from PLN (state power plant) because the distance between the village of Tengah and the village that has been electrified (Lobu Jambang) is around 7 km. With that distance. access to get electricity from PLN is very difficult and requires a very large cost, especially since the population in the village of Tengah is less than 100 families (heads of families).

Analysis of the strength of the Pelton turbine blade with a casting process using a mixture of aluminum materials that were analyzed (Area 2023). And the test results, it can be concluded that Aluminum and a mixture of silicon and manganese powder with variations in oil cooling media are the best to be used as materials with finished mold products in metal casting in the form of Pelton turbine blades [4].

From the research results (Niharman 2021) it can be concluded that at constant pressure, the number of blades affects the performance of the Pelton turbine. In this case, the rotation and load that can be achieved by a turbine with 12 blades is greater when compared to a turbine using 9 blades. The same applies to efficiency, where a Pelton turbine with 12 blades has a higher efficiency than a turbine with 9 blades, namely 79% for 12 blades and 71% for 9 blades respectively.[5]

B. Problem Limitation

Based on the premises explained above, the formulation of the problem in this study is as follows:

1. How is the design of a pelton turbine in the village of tengah hamlet pungga, parmonangan sub-district, north tapanuli with a water fall height of 31 meters and a discharge of 0.016m^3/s.
2. The design of the pelton turbine is carried out in order to be more optimal in utilizing water as a source of electrical energy. in the village of tengah hamlet pungga, parmonangan sub-district, north tapanuli.

C. Research Objectives

1. Designing a pelton turbine according to the needs of the village of tengah hamlet pungga, parmonangan sub-district, north tapanuli with a capacity of 5 kw.
2. Making a pelton turbine prototype.
3. Determining the design of a pelton type water turbine with a water capacity of 0.016m^3/s.
4. Obtaining turbine design data with a field analysis model.

D. Benefits of Research

1. For writers/readers, it can increase knowledge about pelton type turbines.
2. Can be a reference for subsequent researchers in the field of technology
3. Increase knowledge about planning a Pelton turbine type microhydro power plant.

E. History of the vilage of Punggah

The village of Tengah, Dusun Punggah, Parmonangan District, North Tapanuli Regency is located on a mountain far from the reach of the Parmonangan District, this is what causes them to not have received electricity from PLN (state power plant) because the distance between the village of Tengah and the village that has been electrified (Lobu Jambang) is around 7 km. with such a long distance, access to get electricity from PLN is very difficult and requires a very large cost, especially since the population in the village of Tengah is less than 100 families (heads of families).

During the observation/review at the location, the most appropriate type of power plant is the type of hydroelectric power plant PLTMH (micro hydro power plant) where not far from the village location there is a river that has a water discharge and height sufficient to be used as a turbine-type power plant, from the data obtained in the field the planned location of the power plant is at coordinates 10 59'46 "N, 980 45'42" E. This place is closest to the village location and has a sufficient amount of water discharge.

PLTMH is an abbreviation for Micro Hydro Power Plant. PLTMH is a small-scale power plant that uses flowing water as an energy source. PLTMH uses water discharge to drive a turbine which then produces mechanical energy. This mechanical energy drives the generator and produces electricity.

PLTMH can use water from rivers, irrigation channels, or natural waterfalls. PLTMH is an alternative power plant that is environmentally friendly. PLTMH is a renewable energy source and deserves to be called clean energy because it is environmentally friendly.

Turbines can also be classified into two main types: reaction turbines and impulse turbines. Reaction turbines convert all available water energy. In impulse turbines, the runner rotates due to the blowing of water jets that have speed, where the pressure is collected from the pressure of the height when it exits the nozzle.

F. Water Turbine

A water turbine is a system designed to produce electrical energy. The way a water turbine works is by utilizing the height of falling water to create kinetic energy, and the kinetic energy is used to rotate a generator, so that the generator can convert the kinetic energy into electrical energy. The following are the types of water turbines.

G. Generator generator

An electric generator is a device that functions to convert mechanical energy into electrical energy. One of the main working principles of an electric generator is electromagnetic induction. Based on the type of electric current produced, generators are categorized into direct current generators and alternating current generators.

The main difference between the two lies in the use of commutators in direct current generators and slip rings in alternating current generators. The working process of an electric generator is also known as a power generation system. In addition, electric generators have many similarities to electric motors, but electric motors function to convert electrical energy into mechanical energy.[15].

II. Method

A. Final Project Location.

The making of this final project started in June and was carried out in the mechanical engineering laboratory of Harapan University Medan which is located at Jl. HM. Joni No. 70 C, Teladan Barat., Medan Kota District, Medan City, North Sumatra 20216. in Tengah Village, Pungga Hamlet, Parmonangan District.

B. Location of the Planned Power Plant Construction

Tengah Village, Pungga Hamlet, Parmonangan District, North Tapanuli Regency 1°59'46.02, 98°45'42.31

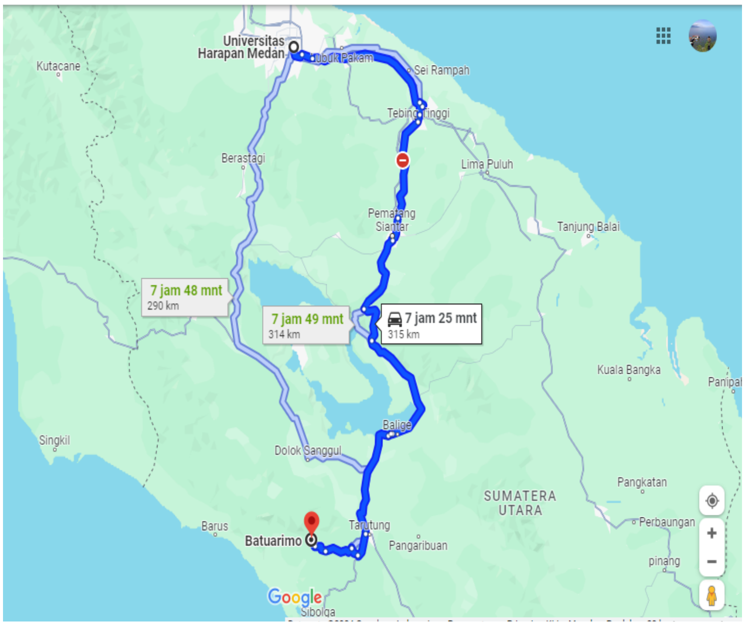

Fig. 1. Distance to the power plant construction site

Fig. 2. Power plant location

III. Results

1. Calculation Results

In designing a Pelton type turbine, a number of parameters are required. To obtain accurate calculation results, initial data is required as a reference in determining the required parameters. This initial data was obtained from Tengah Village, Punggah Hamlet, Parmonangan District, North Tapanuli Regency.

2. Initial Data

The data used in this final project was obtained from Tengah Village, Punggah Hamlet, Parmonangan District, North Tapanuli Regency. Data collection was carried out by considering the effective head of the installation of 31 meters, so that the following data were obtained:

- capacity (Q) = 0.016 m^3/s
- Head = 31 meters
- Water density = 1000 kg/m^3

A Pelton turbine impeller is designed with the following planning specifications:

- turbine rotation = 480 rpm
- turbine efficiency = 80%

Table 1. Nozzle Calculation Result Parameters

No	Parameters	Value
1	Calculation of jet velocity (C_1)	$24{,}16\ m/s$
2	Nozzle jet diameter (d_O)	$20\ mm$
3	Water jet area on nozzle (A)	$314\ mm$
4	Nozzle opening radius (R_1)	$14{,}5\ mm$
5	Needle clearance with nozzle (C)	$12{,}76\ mm$

Tabel 2. Calculation Result Parameters for Spoon and Runner

No	Parameters	Value
1	Runner diameter(D)	$421\ mm$
2	Calculation of the number of blades (z)	$33\ buah$
3	Calculation of the blade width (b)	$64\ mm$
4	Calculation of the blade length (h)	$70\ mm$
5	Calculation of the outer diameter of the runner(D_O)	$505\ mm$
6	Calculation of the blade depth (t)	$19\ mm$
7	Width of the blade opening (a)	$29\ mm$
8	Depth of the blade opening (h_1)	$7\ mm$
9	Calculation of the distance of the water jet center opening (h_2)	$22\ mm$

3. Calculation (flywheel)

This section will discuss the calculation of the flywheel component on the Kinetic Flywheel Conversion I (KFCI) device, which has the following specifications:

Flywheel Specifications The following are the flywheel component specification data on the Pelton turbine used in the calculation.

- flywheel mass = 30 kg
- flywheel outer diameter = 425 mm
- flywheel inner diameter = 340 mm
- flywheel thickness = 58 mm
- Generated rotation = 480 rpm
- Minimum rotation = 0 rpm

4. Pelton Turbine Design Drawing

The following is the design of a Pelton turbine for a micro-hydro power plant with a water fall height of 31 meters and a water flow rate of 0.016m^3/scan be seen in Figure 3.

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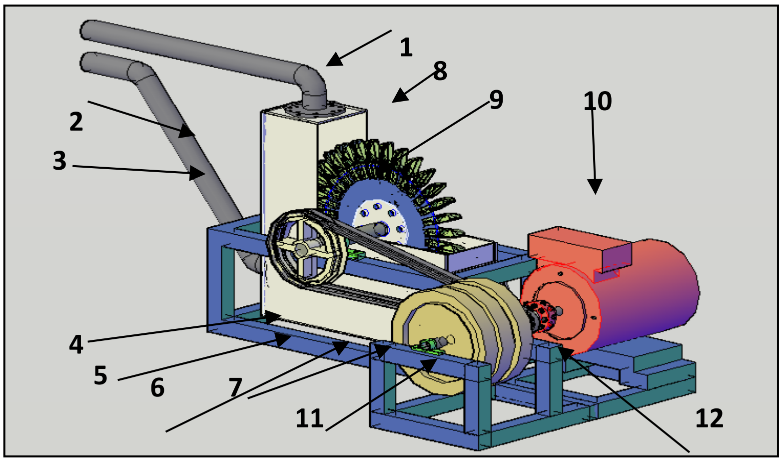

Fig. 3. Draft Drawing

Image caption:

1. Nozzle one	7. Flywheel
2. Nozzle two	8. Turbine runner
3. Turbine frame	9. Shaft
4. Pulley	10. Generator
5. Turbine housing	11. Bearing
6. V belt	12. Clutch

IV. Conclusion

The results of the design parameters for the 5 kW Pelton turbine in Tengah Village, Pungga Hamlet, Parmonangan District, North Tapanuli, can be seen in table 5.1

Table 3. Results of the design parameters for the 5 kW Pelton turbine

NO	Parameters	Value
1	Jet velocity calculation (C_1)	24,16 m/s
2	Nozzle jet diameter(dO)	20 mm
3	Water jet area on nozzle (A)	314 mm
4	Nozzle opening radius (R_1)	14,5 mm
5	Clearance between needle and nozzle(C)	12,76 mm
6	Runner diameter(D)	421 mm
7	Blade number calculation (z)	33 $buah$
8	Blade width calculation (b)	64 mm
9	Blade length calculation (h)	70 mm
10	Runner outer diameter calculation(D_O)	505 mm
11	Blade depth calculation (t)	19 mm
12	Blade opening width (a)	29 mm
13	Blade opening depth (h_1)	7 mm
14	Blade center opening distance calculation (h_2)	22 mm
15	Flywheel Angular Velocity (ω)	50,24 rad/s
16	Flywheel Mass Moment of Inertia (I)	0,108 $kg.m^2$
17	Flywheel Torque (T)	0,360 Nm
18	Blade power calculation (Pd)	5 kw
19	Torque (T)	10 145 Nm
20	Allowable shear stress (τa)	7,9 (kg. mm)
21	calculation of shaft diameter (ds)	21,41 mm
22	Belt planning moment power (Pd)	5kw

NO	Parameters	Value
23	Belt torque moment (T)	5009,14 kgf.mm
24	calculation of the diameter of the driven pulley (n_2)	1920 Rpm
25	Distance of the axis of the shaft (c) and belt length (L)	$2\,451{,}7\ mm$
26	Linear velocity (v)	$10{,}2\ m/s$
27	Circumferential force on the belt (F)	90
28	Tension on the belt (σ_d)	$21{,}6\ kg/cm^2$
29	Number of belts needed (z)	$5\ buah$

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